

# **IMMUNOGLOBULIN SUPERFAMILY VARIANTS EXPRESSED IN MESENCHYMAL CELLS AND THERAPEUTIC USES THEREOF**

## **CROSS-REFERENCE TO RELATED APPLICATIONS**

5           This application is a continuation of the International Application PCT/IL02/00129 filed February 20, 2002, the entire content of which is expressly incorporated herein by reference thereto, which application claims priority to Israel Patent Application Nos. 141539 and 145658 filed February 20, 2001 and September 25, 2001, respectively.

## **FIELD OF THE INVENTION**

10           The present invention relates to novel transcripts of immunoglobulin superfamily genes, particularly T cell receptor (TCR) and immunoglobulin heavy chain variants expressed on mesenchymal and endothelial cells, said variants useful in mediating intercellular interactions between the mesenchyme and/or endothelium and other cell types, thereby regulating stem cell  
15           growth and differentiation.

## **BACKGROUND OF THE INVENTION**

### **T Cell Receptors**

20           Major Histocompatibility Complex (MHC)-restricted T cells express heterodimeric surface protein receptors ( $\alpha\beta$ TCR) co-localized with up to five additional non-variant membrane receptors (Strominger, 1989; Abbas et al., 1994; Jameson et al., 1995). This TCR complex specifically binds processed peptide antigens associated with MHC molecules. The interactions of TCR with MHC bound peptides on various target cells may have consequences both in terms of T cell proliferation and in activation of effector mechanisms leading to target cell killing, graft  
25           rejection, and other biological effects.

30           Functional TCR  $\alpha$  and  $\beta$  chain genes, which are capable of being expressed as polypeptides, are normally present only in cells of the T lymphocyte lineage. These functional TCR genes are formed by somatic rearrangement of germline gene segments. Each TCR locus consists of variable (V), joining (J), and constant (C) region genes, and the  $\beta$  chain locus contains diversity (D) gene segments. In mice there are 20 to 30 V $\beta$  gene segments that are located 5' of the two clusters of C and J segments. There is a single C $\alpha$  gene associated with a large 5' cluster of up to 50 different J segments and about 75 V $\alpha$  segments. There is a large region of intervening DNA between V $\alpha$  and J $\alpha$  exons, which includes the entire TCR  $\delta$  chain locus. During maturation of T cells in the thymus, the TCR segments are rearranged in a defined order, resulting in the  
35           formation

of functional TCR $\alpha$  and  $\beta$  genes in which V, D, J and C segments are in close proximity to each other.

The  $\beta$  chain locus rearranges prior to the  $\alpha$  locus. The primary transcripts contain noncoding intronic sequences between the VDJ and C genes, which are later  
5 spliced out. The functional T cell receptor is comprised of 2 polypeptides: the  $\alpha$  chain is a 40 to 60 kD acidic glycoprotein, and the  $\beta$  chain is a 40 to 50 kD uncharged or basic glycoprotein. The V and C regions of  $\alpha$  and  $\beta$  chains form intrachain disulfide bond loops, which might contribute to the formation of a tertiary structure and are presented on the cell membrane. The C region contains the transmembrane domain and a short  
10 cytoplasmic tail thought to be too small to have intrinsic signal transducing properties.

T cells (Qian et al., 1993; Yoshikai et al., 1984) as well as B cells (Calman and Peterlin, 1986) express a series of incomplete transcripts of TCR $\alpha$  and  $\beta$ , that vary in size and structure. These transcripts may be out of frame or their sequence may contain many stop codons. In some cases mRNAs encoding the constant region flanked by an  
15 upstream spliced J segment were identified. In one case such a transcript of human TCR $\beta$ , which contains an in-frame codon for methionine, has been reported (Fagioli et al., 1991). However, no evidence for the existence of a protein encoded by these transcripts in T cells has been documented. TCR transcripts have also been reported in cell lineages other than T or B lymphocytes. Thus, TCR $\alpha$  mRNA was identified in  
20 murine kidney (Madrenas et al., 1991; Madrenas et al., 1992; Madrenas et al., 1994). A recent study identified in epithelial tumor cells a partial TCR $\gamma$  chain mRNA, lacking the V region. This mRNA encodes a 7 kDa protein, TARP, which is translated from an alternate reading frame and is therefore not homologous to the TCR $\gamma$  protein (Essand et al., 1999; Wolfgang et al., 2000). No evidence for TCR $\alpha\beta$  or TCR $\delta$  transcripts or  
25 proteins was found in that study. It is therefore generally accepted that TCR $\beta$  transcripts are not found outside of the lymphocyte lineage and that TCR protein expressed at the cell surface is a specific T cell trait.

Nevertheless, it is possible that the TCR gene family serves functions other than those already ascribed to it. The laboratories of the present inventors and colleagues  
30 have now discovered that primary mesenchyme, as well as mesenchymal cell clones, express T cell receptor (TCR) $\alpha\beta$  mRNAs, lacking the variable region. Immunological

and genetic evidence support the expression of a corresponding TCR $\beta$  protein. This truncated TCR protein is implicated in the regulation of mesenchymal cell growth (Barda-Saad, et al. Oncogene, in press, 2002).

## 5    **The pre B cell receptor (preBCR)**

In the bone marrow, B cell development can be divided into different stages, based on the rearrangement status of the IgH and IgL chain loci (Ehlich et al 1994; ten Boekel et al 1997) and the expression of intracellular and surface-bound markers. The pre-B cell receptor consists of immunoglobulin  $\mu$  heavy chains and surrogate light chain, the VpreB and  $\lambda 5$  proteins (Hardy et al 1991).

Immunoglobulins (Igs) are synthesized exclusively by B lymphocytes (Abbas et al 1994). The immunoglobulin molecule can exist in two very different environments: at the cell membrane as a surface antigen receptor and in solution as a secreted antibody. The immunoglobulin molecule is composed of two identical light chains and two identical heavy chains. The light and heavy chains can each be divided into an N terminal variable (V) and a C terminal constant (C) region. The V regions are responsible for antigen binding, whereas the C regions embody the various effector functions of the molecule. The various classes of immunoglobulins with different functions (IgM, IgD, IgG, IgA, IgE) are distinguished by different heavy chains ( $\mu$ ,  $\delta$ ,  $\gamma$ ,  $\alpha$ ,  $\epsilon$ ), with the difference residing in their C<sub>H</sub> regions (C $\mu$ , C $\delta$ , C $\gamma$  C $\alpha$ , C $\epsilon$ ) (Rogers et al 1980).

B lymphocytes mature from hemopoietic stem cells through a series of developmental stages that are characterized by sequential DNA rearrangements of Ig gene segments. The rearrangement of Ig genes allows B cells to respond to a wide spectrum of foreign antigens (Ags). The V, D and J segments encoding parts of the IgH and the V and J segments of IgL-chains are rearranged in a stepwise fashion (Melchers, & Rolink 1999). ProB cells begin to rearrange D<sub>H</sub> to J<sub>H</sub> segments of the H chain locus, so that in PreBI cells (B220<sup>+</sup>, c-kit<sup>+</sup>) both H-chain alleles are D<sub>H</sub>J<sub>H</sub> rearranged. ProB and PreBI cells already produce surrogate light chains VpreB and  $\lambda 5$  in preparation for the formation of the preBCR (Melchers et al 1993). When V<sub>H</sub> to D<sub>H</sub> to J<sub>H</sub> rearrangements are initiated in PreBI cells, those rearrangements that are in frame will generate a functional IgH chain gene.

The formation of the preBCR has a functional consequence for precursor B cells. PreBII cells are stimulated to undergo between two and five rounds of divisions (Rolink et al 2000) and to expand the number of  $\mu$ H chain producing preBII cells in which, subsequently, L-chain rearrangements are initiated. The preBCR signals for the inhibition of rearrangements at the second D<sub>H</sub> J<sub>H</sub> - rearranged H chain allele (allelic exclusion) (Ehlich et al 1994; ten Boekel et al 1997). Subsequent processing of the RNA leads to splicing out of the intron between the VDJ complex and the most proximal C region gene, which is the C- giving rise to a functional mRNA for the  $\mu$  heavy chain.

The recombination activating genes, RAG-1 and RAG-2, are essential for V(D)J recombination (Shinkai et al 1992, Mombaerts et al 1992). During B lineage development in adult mice, RAG-1 and RAG-2 are expressed exclusively in early B progenitors of the bone marrow and expression ceases prior to the migration of B lineage cells from the bone marrow (Hardy et al 1991; Osmond 1990). Furthermore, mice that lack either RAG-1 or RAG-2 fail to develop mature lymphocytes due to their inability to initiate rearrangement of the antigen receptor genes (Shinkai et al 1992; Mombaerts et al 1992). However, expression of a rearranged  $\mu$ HC transgene in the RAG-deficient background partially rescued this developmental block in the B lineage, leading to the generation of B220<sup>+</sup>CD43<sup>-</sup> pre-B cells, demonstrating that  $\mu$  chain expression was sufficient to drive this developmental transition (Young et al 1994, Spanopoulou et al 1994).

$\mu$  chains of membrane ( $\mu_m$ ) and secreted ( $\mu_s$ ) forms differ in structure. The  $\mu_m$  chain is larger than the  $\mu_s$  chain and has hydrophobic properties not exhibited by the  $\mu_s$  (Rogers et al 1980). An essential role for components of the preBCR complex has been established. Targeted disruption of the membrane exons of the  $\mu$ H chain, or the  $\lambda 5$  locus, result in the failure of normal B cell development and the loss of allelic exclusion in pre-B cells (Kitamura et al 1991; Kitamura et al 1992a; Kitamura et al 1992b; Loffert et al 1996). PreB cells can express  $\mu_s$  chains as well as,  $\mu_m$  chains providing a potential source for a soluble form of preBCR. The  $\mu_s$  chains can associate with SLC and assemble into a soluble preBCR complex in preB cells.  $\mu_s$  chains can associate with SLC internally, but are efficiently retained and degraded. Mutation of a single cysteine (Cys575) in the  $\mu_s$

tailpiece (tp) results in the release of soluble preBCR from the endoplasmic reticulum (ER) and its subsequent secretion.

The soluble preBCR does not bind the hapten recognized by antibody (Ab) consisting of the same heavy chain V region paired with a conventional L chain,  
5 consistent with the preBCR having a unique specificity (Bornemann et al 1997).

Because the preBCR, like the mature BCR, has no known intrinsic enzymatic functions, it must rely upon associated proteins to provide a functional linkage with intracellular signaling pathways. The mature and preBCR-associated Ig $\alpha$  and Ig $\beta$  chains contain immunoreceptor tyrosine-based activation motifs (ITAMs), which are targets for  
10 phosphorylation by tyrosine kinases (Reth 1984); these proteins are required for normal B cell development (Gong & Nussenzweig 1996; Torres et al 1996). Furthermore, the importance of an ITAM-associated tyrosine kinase activity during early B lymphopoiesis was demonstrated in mice deficient in the syk tyrosine kinase, in which an incomplete block in development was observed at the B220<sup>+</sup>CD43<sup>+</sup> proB cell stage (Cheng, et al  
15 1995; Turner et al 1995).

#### **Truncated heavy chain D $\mu$**

Reth & Alt discovered in 1984 (Reth and Alt 1984) a truncated D $\mu$  heavy chain in a permanent lymphoid cell line, which represents a pre B stage of B-lymphocytes, by  
20 transformation of bone marrow or fetal calf liver cells with Abelson murine leukemia virus (A-MuLV). Some A-MuLV generated lines produce an unusually small  $\mu$  heavy chain mRNA and sometimes a small  $\mu$  protein. The short  $\mu$  mRNA sequences arise from the transcription of DJ<sub>H</sub> rearrangements and the short  $\mu$  proteins from the translation of the resulting DJ<sub>H</sub> C $\mu$  containing mRNAs (D $\mu$  mRNA). Due to an inexact  
25 joining mechanism, the D<sub>H</sub> can be rearranged to the J<sub>H</sub> in three possible reading frames (RFs). A majority of the D<sub>H</sub> segments carry their own promoter and an ATG translational initiation codon. When the D<sub>H</sub> is rearranged to a J<sub>H</sub> in RF2, according to the nomenclature of. (Ichihara et al 1989), this D<sub>H</sub>J<sub>H</sub> complex can be translated into a truncated  $\mu$  chain protein. The size of these small  $\mu$  chains was analyzed by Western  
30 blot using anti-IgM antisera and <sup>125</sup>I-labelled monoclonal IgM antibody. Lysates from control transformant express normal-sized  $\mu$ -chains of 70Kd molecular weight while cell lines express an abnormally small  $\mu$  protein of approximately 57Kd. Furthermore,

instead of normal 2.4 and 2.7 kb  $\mu$  mRNAs which encode, respectively, the secreted and membrane-bound forms of the  $\mu$  proteins, cell lines 300-19 and 298-13 (Reth and Alt 1984) contain truncated C $\mu$ -specific RNAs of 2.0 and 2.3 kb; these species contain 3' ends specific to the membrane and secreted forms of the protein, respectively. D $\mu$  preBCR can mediate a block in B cell development, probably by inhibiting V<sub>H</sub> to D<sub>H</sub>J<sub>H</sub> rearrangements, as well as inducing V<sub>L</sub> to J<sub>L</sub> rearrangements (Tomberg et al 1998, Horne et al 1996).

There is an unmet need for and it would be advantageous to have polypeptide or peptide markers for mesenchymal cells that are involved in control of proliferation and differentiation of hemopoietic stem cells. In addition, it would be advantageous to develop interventive therapeutic strategies based either on gene therapy or antisense molecular therapy to treat disorders involving the proliferation and differentiation of hemopoietic stem cells.

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#### SUMMARY OF THE INVENTION

It is an object of the present invention to provide polypeptide or peptide markers for mesenchymal cells that are involved in control of proliferation and differentiation of hemopoietic stem cells. It is another object of the present invention to provide methods for intervening therapeutically utilizing methods of gene therapy or antisense molecular therapy to treat disorders involving the proliferation and differentiation of hemopoietic stem cells.

The present invention discloses novel transcripts of Immunoglobulin (Ig) superfamily genes, particularly T cell receptor (TCR) and Ig heavy chain variants, expressed on mesenchymal and endothelial cells which are mediators of intercellular

interactions leading, either directly or indirectly, to modulation in the proliferation and differentiation of their neighboring cells.

More preferably, the mesenchymal TCR or Ig variants are either directly or indirectly involved in the regulation of stem cell growth and differentiation. The therapeutic uses of these molecules are also disclosed.

The growth and differentiation of normal cells and malignant tumors within different tissues, are all dependent on mesenchymal cellular interactions, as is known in the art. It is now disclosed that the lack of the TCR in mesenchymal cells causes loss of the ability of the mesenchyme to support hemopoiesis.

The present invention also relates to truncated immunoglobulin (Ig) transcripts and encoded proteins found in mesenchymal and endothelial stromal cells as detailed herein below, and to the uses of these molecules.

The present invention relates, in one aspect, to cDNA molecules encoded by immunoglobulin genes, said cDNA molecules lacking V region and comprising a constant (C) domain and a joining (J) region sequences, and a 5' intronic J sequence upstream said J region sequence including an in-frame methionine codon. The novel polynucleotides of the invention are exemplified herein by transcripts of Ig  $\mu$  chains, expressed in mesenchymal and endothelial cells.

The novel polynucleotide sequences disclosed herein and the corresponding proteins, polypeptides or peptides encoded by these polynucleotide sequences may be derived from any mammalian species including human genetic material.

In one embodiment of the invention, the cDNA molecule encodes a truncated  $\mu$  heavy chain transcript from the mouse cell line MBA-2.1 with the sequence:

atgggtttttgtacaccactaaaggggtctatgatagtgtgac

tactttgactactggggccaaggcaccactctcacagtctcctca [SEQ ID NO:1]

which codes for the peptide:

MGFCTPTKGVYDSVTTLTTGAKAPLSQSPS [SEQ ID NO:2]

In another embodiment of the invention, the truncated  $\mu$  heavy chain 5'end begins from a joining region 4 (J4), and comprises a constant region and a transmembrane domain:

atg gac tac tgg ggt caa gga acc tca gtc acc gtc tcc tca

Constant

5 gagagtcagtccttcccaaagtcttccccctcgtctcctgcgagagc  
cccctgtctgataagaatctggtggccatgggctgcctggccccgggac  
ttcctgcccagcaccatttcttccactggaactaccagaacaacact  
gaagtcattccaggggtatcagaaccttcccaacactgaggacagggggc  
aagtacctagccacctcgaggtcttgctgtctcccaagagcatcctt  
gaagggttcagatgaataccttgatgcaaaatccactacggaggcaaa  
10 aacagagatctgcatgtgcccattccagctgtcgagagatgaatccc  
aatgtaaatgtgttcgtcccaccacgggatggcttctctggccctgca  
ccacgcaagtctaaactcatctgcgaggccacgaacttcaactccaaaa  
ccgatcacagtatcctggctaaaggatgggaagctcgtggaatctggc  
ttcaccacagatccgggtgaccatcgagaacaaaggatccacaccccaa  
15 acctacaagggtcataagcacacttaccatctctgaaatcgactggctg  
aacctgaatgtgtacacctgccgtgtggatcacaggggtctcaccttc  
ttgaagaacgtgtcctccacatgtgctgccagagggtccctccacagac  
atcctaaccttcacacatccccccctcctttgccgacatcttctcagc  
aagtcgctaacctgacctgtctggtctcaaacctggcaacctatgaa  
20 accctgaatatctcctgggcttctcaaagtgggaaccactggaaacc  
aaaattaaaatcatggaaagccatcccaatggcaccttcagtgtctaa  
gggtgtggctagtgtttgtgtggaagactggaataacaggaaggaattt  
gtgtgtactgtgactcacagggatctgccttcgccacagaagaaattc  
atctcaaaacccaatgaggtgcacaaacatccacctgctgtgtacctg  
25 ctgccaccagctcgtgagcaactgaacctaaagagagtcagccacagtc  
acctgcctgggtgaagggttctctcctgcagacatcagtgtgcagtgg  
cttcagagagggcaactcttgcccccaagagaagtatgtgaccagtgc  
ccgatgccagagcctggggccccagggttctactttaccacagcatc  
ctgactgtgacagaggaggaatggaactccggagagacctataacctgc  
30 gttgtagggcacgaggccctgccacacctagtgaaccgagaggaccgtg  
gacaagtccact

Transmembrane domain

35 gagggggaggtgaatgctgaggaggaaggctttgagaacctgtggacc  
actgcctccaccttcaccttcacgtcctcttctcctgagcctcttc  
tacagcacctgcacctgttcaagggtgaaa (tga) [SEQ ID NO:3]

In another embodiment of the invention, the truncated  $\mu$  heavy chain 5'end comprises a  
40 joining region 4 (J4), a constant region and a cytoplasmic domain:

atg gac tac tgg ggt caa gga acc tca gtc acc gtc tcc tca

Constant

45 gagagtcagtccttcccaaagtcttccccctcgtctcctgcgagagc  
cccctgtctgataagaatctggtggccatgggctgcctggccccgggac  
ttcctgcccagcaccatttcttccactggaactaccagaacaacact  
gaagtcattccaggggtatcagaaccttcccaacactgaggacagggggc

aagtacctagccacctcgcaggtcttgctgtctcccaagagcatcctt  
 gaagggttcagatgaataccttgatgcaaaatccactacggaggcaaa  
 aacagagatctgcatgtgccattccagctgtcgcagagatgaatccc  
 5 aatgtaaagtgtgttcgtcccaccacgggatggcttctctggccctgca  
 ccacgcaagtctaaactcatctgcgaggccacgaacttcaactccaaaa  
 ccgatcacagtatcctggctaaaggatgggaagctcgtggaatctggc  
 ttcaccacagatccggtgaccatcgagaacaaaggatccacaccccaa  
 acctacaagggtcataagcacacttaccatctctgaaatcgactggctg  
 10 aacctgaatgtgtacacctgccgtgtggatcacaggggtctcaccttc  
 ttgaagaacgtgtcctccacatgtgctgccagaggtccctccacagac  
 atcctaaccttcaccatccccccctccttggcgacatcttctcagc  
 aagtccgctaacctgacctgtctggctctcaaactgggcaacctatgaa  
 accctgaatatctcctgggcttctcaaagtggatgaaccactggaaacc  
 aaaattaaaatcatggaaagccatcccaatggcaccttcagtgtctaa  
 15 ggtgtggctagtgtttgtgtggaagactggaataacaggaaggaattt  
 gtgtgtactgtgactcacagggatctgccttcgccacagaagaaattc  
 atctcaaaaacccaatgaggtgcacaaacatccacctgctgtgtacctg  
 ctgccaccagctcgtgagcaactgaacctaaagagagtcagccacagtc  
 acctgcctgggtgaagggttctctcctgcagacatcagtgtgcagtgg  
 20 cttcagagagggcaactcttgccccaagagaagtatgtgaccagtgcc  
 ccgatgccagagcctggggccccaggcttctactttaccacagcatc  
 ctgactgtgacagaggaggaatggaactccggagagacctataacctgc  
 gttgtaggggcacgaggccctgccacacctagtgaccgagaggaccgtg  
 gacaagtccact  
 25

Cytoplasmic domain

ggtaaaccacactgtacaatgtctccctgatcatgtctgacacagggc  
 ggcacctgctat (tga) [SEQ ID NO:4]

30 In another embodiment of the invention, the truncated  $\mu$  heavy chain 5'end extends  
 from the constant region and comprises the transmembrane domain:

atgggctgcctggccgggacttccctgccagcaccatttccttcacc  
 tggaaactaccagaacaacactgaagtcatccagggtatcagaaccttc  
 ccaacactgaggacagggggcaagtacctagccacctcgcaggtcttg  
 35 ctgtctcccaagagcatccttgaagggttcagatgaataccttgatgc  
 aaaatccactacggaggcaaaaacagagatctgcatgtgccattcca  
 gctgtcgcagagatgaatcccaatgtaaagtgttcgtcccaccacgg  
 gatggcttctctggccctgcaccacgcaagtctaaactcatctgcgag  
 gccacgaacttcaactccaaaacgatcacagtatcctggctaaaggat  
 40 gggaagctcgtggaatctggcttcaccacagatccggtgaccatcgag  
 aacaaaggatccacaccccaaacctacaagggtcataagcacacttacc  
 atctctgaaatcgactggctgaacctgaatgtgtacacctgccgtgtg  
 gatcacaggggtctcaccttcttgaagaacgtgtcctccacatgtgct  
 gccagaggtccctccacagacatcctaaccttcaccatccccccctcc  
 45 tttggcgacatcttctcagcaagtccgctaacctgacctgtctggctc  
 tcaaactggcaacctatgaaacctgaatatctcctgggcttctcaa  
 agtggatgaaccactggaaaccaaattaaaatcatggaaagccatccc

aatggcaccttcagtgctaaggggtgtggctagtgtttgtgtggaagac  
 tggaataacaggaaggaatttgtgtgtactgtgactcacagggatctg  
 ccttcgccacagaagaaattcatctcaaaacccaatgaggtgcacaaa  
 catccacctgctgtgtacctgctgccaccagctcgtgagcaactgaac  
 5 ctaagagagt cagccacagt cacctgcctgggtgaagggcttctctcct  
 gcagacatcagtggtcagtggttcagagaggggcaactcttgccccaa  
 gagaagtatgtgaccagtgtcccgatgccagagcctggggccccaggc  
 ttctactttaccacagcatcctgactgtgacagaggaggaatggaac  
 tccggagagacctatacctgcgttgtagggcacgagggcctgccacac  
 10 ctagtgaccgagaggaccgtggacaagtcact

# Transmembrane domain

Gagggggaggtgaatgctgaggaggaaggctttgagaacctgtggacc  
 Actgcctccaccttcaccttcacgtcctcttccctcctgagcctcttc  
 15 tacagcacctgcacctgttcaaggtgaaa (tga) [SEQ ID NO:5]

In another embodiment of the invention, the truncated  $\mu$  heavy chain 5'end begins from  
 the constant region and comprises the cytoplasmic domain:

20 atgggctgcctggcccggaacttccctgccagcaccatttccttcacc  
 tggaactaccagaacaacactgaagtcacccagggtatcagaaccttc  
 ccaacactgaggacagggggcaagtacctagccacctcgcaggtcttg  
 ctgtctcccaagagcatccttgaaggttcagatgaataccttgtatgc  
 25 aaaatccactacggaggcaaaaacagagatctgcatgtgccattcca  
 gctgtcgcagagatgaatcccaatgtaaatgtgttcgtcccaccacgg  
 gatggcttctctggccctgcaccacgcaagtctaaactcatctgcgag  
 gccacgaacttcactccaaaaccgatcacagtatcctggctaaaggat  
 gggaaagctcgtggaatctggcttcaccacagatccgggtgaccatcgag  
 30 aacaaaggatccacacccccaaacctacaaggtcataagcacacttacc  
 atctctgaaatcgactggctgaacctgaatgtgtacacctgccgtgtg  
 gatcacaggggtctcaccttcttgaagaacgtgtcctccacatgtgct  
 gccagaggtccctccacagacatcctaaccttcaccatccccccctcc  
 tttgccgacatcttccctcagcaagtcogctaacctgacctgtctggtc  
 35 tcaaacctggcaacctatgaaacctgaatatctcctgggcttctcaa  
 agtgggtgaaccactggaaaccaaattaaaatcatggaaagccatccc  
 aatggcaccttcagtgctaaggggtgtggctagtgtttgtgtggaagac  
 tggaataacaggaaggaatttgtgtgtactgtgactcacagggatctg  
 ccttcgccacagaagaaattcatctcaaaacccaatgaggtgcacaaa  
 40 catccacctgctgtgtacctgctgccaccagctcgtgagcaactgaac  
 ctaagagagt cagccacagt cacctgcctgggtgaagggcttctctcct  
 gcagacatcagtggtcagtggttcagagaggggcaactcttgccccaa  
 gagaagtatgtgaccagtgtcccgatgccagagcctggggccccaggc  
 ttctactttaccacagcatcctgactgtgacagaggaggaatggaac  
 45 tccggagagacctatacctgcgttgtagggcacgagggcctgccacac  
 ctagtgaccgagaggaccgtggacaagtcact

Cytoplasmic domain  
Ggtaaaccacactgtacaatgtctccctgatcatgtctgacacaggc  
ggcacctgctat(tga) [SEQ ID NO:6]

5

In another aspect, the invention relates to antisense DNA molecules of the cDNA molecules of the invention described hereinabove.

10 The invention further relates to expression vectors comprising the cDNA and antisense molecules of the invention, and to host cells, particularly mammalian cells, comprising said vectors. In one preferred embodiment the host cells are transfected mesenchymal or endothelial human cells.

15 The cDNA of the invention can be used to transfect mesenchymal and endothelial human cells for mediating their intercellular functions. Thus, the invention relates to compositions comprising said transfected mesenchymal and endothelial human cells for use in disorders requiring modulation of their intercellular functions, such as wound healing

20 The invention further relates to a method for modulating mesenchymal and endothelial intercellular functions comprising the step of administering to a subject in need thereof transfected mesenchymal and endothelial human cells comprising a cDNA molecule according to the invention, in an amount effective to augment their intercellular communication. Preferably, these transfected mesenchymal or endothelial cells are autologous cells.

25 According to one currently preferred embodiment these methods are applicable for inducing or enhancing wound healing. According to another currently preferred embodiment, this method is applicable for augmenting hemopoiesis in autologous or allogeneic bone marrow transplantation. These methods can be carried out as *in vitro*, *ex vivo* or *in vivo* procedures, especially in the form of gene therapy.

30 Alternatively and preferably, antisense molecules of the invention are useful in the treatment of malignant diseases in general where there is a tendency for the carcinoma cells to spread to the patient's bone marrow. The method can be carried out as an *in vitro*, *ex vivo* or *in vivo* procedure, especially in the form of gene therapy, or antisense therapy.

The antisense DNA molecules of the invention can be used to transfect mesenchymal and endothelial human cells for inhibiting or suppressing their intercellular interactions. Thus the invention relates to compositions comprising said transfected mesenchymal and endothelial human cells for use in disorders requiring inhibition or suppression of their intercellular interactions, such as in carcinomas.

The invention further relates to a method for suppressing mesenchymal and endothelial cell growth comprising the step of administering to a subject in need thereof antisense DNA, a vector comprising this DNA or transfected mesenchymal and endothelial human cells comprising an antisense DNA molecule of the invention, in an amount effective to suppress their intercellular interactions, such as for suppression of carcinomas. Preferably these transfected mesenchymal or endothelial cells will be autologous.

According to the present invention mesenchymal TCR or Ig transcripts may be either directly or indirectly involved in the regulation of stem cell growth and differentiation. It is anticipated that additional molecular variants of the Ig superfamily will be transcribed in and expressed by mesenchymal and/or endothelial cells and these too are within the scope of the present invention. It will be appreciated by the skilled artisan that additional molecules may be involved in molecular complexes that regulate intercellular interactions together with the novel truncated variants of the present invention. It is also understood that the regulatory effect of the molecules of the invention may be either direct or indirect, the latter term expressing the need for additional molecular mediators or signals to achieve the observed biological effect.

The novel polynucleotide sequences disclosed herein and the corresponding proteins, polypeptides or peptides encoded by these polynucleotide sequences may be derived from any mammalian species including human genetic material.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

**Figure 1 . Defective hemopoietic supporting activity of MEF from TCR $\beta$  deficient mice.**  
(A) Long term proliferation of hemopoietic cells in the liquid phase of co-cultures of bone marrow cells seeded onto confluent cultures of MEF (9<sup>th</sup> *in vitro* passage) from normal embryos (full bars) and from TCR $\beta$ <sup>-/-</sup> mice (empty bars). (B) A photomicrograph of similar

co-cultures in which  $10^3$  FACS sorted  $CD34^+ Lin^-$  cells were seeded onto wild type control MEF (I) as compared to  $TCR\beta^{-/-}$  MEF (II) (C) Proliferation of hemopoietic cells in the liquid phase of cultures seeded with  $CD34^+ Lin^-$  cells. (D) Determinations of hemopoietic colony forming cells in the liquid phase of the cultures shown in (C) at the indicated time points, and at the end of one month culture, within the adherent cell layers (gray bar). Figures are determinations of triplicate cultures  $\pm$  standard deviation of the mean.

**Figure 2.**  $\mu$  heavy chain mRNA transcript detection by Northern blot analysis. Total RNA and poly A+ RNA samples were hybridized with  $\mu$  heavy chain probe. Lane 1 mouse spleen total RNA; Lane 2 MBA-2.1 total RNA; Lane 3 MBA-2.1 poly A+ RNA.

**Figure 3.** Immunoblot analysis of  $\mu$  heavy chain with goat anti mouse-  $\mu$  chain. Cells lysates were loaded on 10% SDS gel and then transferred to nitrocellulose membrane. The membrane was blotted with goat anti-mouse- $\mu$  chain. Lane 1- 70Z cells; Lane 2 - MBA 2.4; Lane 3 – MBA-2.1.

**Figure 4.** Immunostaining of MBA-2.1 cells with goat anti mouse-  $\mu$  chain and amplified with biotinylated donkey anti goat and ABC kit.

#### **DETAILED DESCRIPTION OF THE INVENTION**

The present invention discloses the transcription of novel variants of members of the genes referred to as the Immunoglobulin superfamily, in cells that do not belong to the hemopoietic or lymphoid lineages. Hitherto these molecules were considered to be specific to lymphoid lineages, with the exception of certain transformed cell lines or tumors that were known to express certain abnormal transcripts of these genes. Importantly, the novel transcripts now discovered in mesenchymal cells are also translated and expressed as novel truncated variants of TCR and Ig molecules by these cells.

These novel truncated variants are capable of regulating cell growth and differentiation, as well as mediating cell-cell interactions. These attributes can be used to stimulate cell growth, for instance especially in order to enhance hemopoiesis. These methods should prove particularly useful in situations involving bone marrow transplantation, by way of example. In contradistinction, these attributes can be used to suppress cell growth, for instance in order to prevent cancer growth or metastasis. The growth stimulation might entail gene therapy, while the growth suppression might entail either antisense therapy or antibody targeting or other methods known in the art.

The present invention resulted in part from studies on the interactions of stromal cell lines with thymic T cells, during which we used reverse transcription polymerase chain reaction (RT-PCR) to amplify TCR gene fragments. Unexpectedly, the MBA-13 mesenchymal stromal cell line, derived from mouse bone marrow, was found to consistently express TCR $\beta$  constant (C $\beta$ ) region, while cDNA from a negative control tissue, i.e. liver, and from several control cell lines such as pre-B cells, plasmacytoma and mastocytoma cells, did not produce PCR products using primers from the TCR gene.

Further studies with a variety of stromal cell lines, showed the existence of TCR gene derived mRNAs that encode short versions of the gene consisting of the constant (C) domain, which is identical to that of T cell receptor, a joining (J) region, which may be one of several alternatives, and a 5' sequence corresponding to an intronic J sequence (again one of several alternatives) including an in-frame codon for methionine (see Barda-Saad et al., *Oncogene*, in press 2002). This mRNA lacks V region sequences. One of such molecules, namely a new version of a TCR $\beta$ 2.6, was shown to exist in mesenchymal cells and to encode a cell surface mesenchymal protein. Expression on the mRNA level has also been observed in the thymus (see Barda-Saad et al., *Oncogene*, in press). Table 1 below provides examples of the peptides encoded by the intronic J sequences of these novel transcripts.

The finding that mesenchymal cells express TCR genes raised the possibility that other members of the immunoglobulin (Ig) superfamily are expressed in the mesenchyme. We screened a series of stromal mesenchymal cell lines derived in our laboratory including one subtype that shares properties with endothelial cells (MBA-2.1 cells). Based on our experience with truncated TCR molecules, which were found to be

lacking the variable part and possessing a J region preceded by an intronic sequence including a codon for methionine, we performed a PCR analysis on MBA-2.1 cells and found that they do express mRNA transcripts corresponding to truncated Ig  $\mu$  heavy chains. We thus find that at least one type, and possibly more, of stromal cells express the Ig  $\mu$  chains and may present this protein as a surface molecule.

We further disclose the ability of the truncated immunoglobulin superfamily variants expressed in mesenchymal cells to regulate or modulate growth/differentiation control of their neighboring cells. In other words, not only do the novel molecules of the invention modulate the growth of the mesenchymal cells themselves but they are also capable of regulating the growth and differentiation of hemopoietic stem cells. Moreover, they are capable of regulating the growth of transformed cells.

The present invention discloses the novel uses of the truncated TCR variants as well as the uses of the novel truncated Ig variants.

**Table 1** Truncated TCR variant transcripts from mesenchymal cells comprise intronic J sequences encoding deduced peptides.

MENVSNPGSCIEEGEERGRILGSPFL [SEQ ID NO:7]

MGEYLAEPRGFVCGVEPLC [SEQ ID NO:8]

MAWH [SEQ ID NO:9]

MEAGWEVQHWVSDMECLTV [SEQ ID NO:10]

MECLTV [SEQ ID NO:11]

MTV [SEQ ID NO:12]

MCGSEEVFVVESA [SEQ ID NO:13]

MACYQMYFTGRKVDEPSELGSGL

ELSYFHTGGSSQAVGLFIENMISTS  
HGHFQEMQFSIWSFTVLQISAPGSH  
LVPETERAEGPGVFVEHDI [SEQ ID NO:14]

5 MYFTGRKVDEPSELGSGL  
ELSYFHTGGSSQAVGLFIENMISTS  
HGHFQEMQFSIWSFTVLQISAPGSH  
LVPETERAEGPGVFVEHDI [SEQ ID NO:15]

10 MISTSHGHFQEMQFSIWSFTVLQIS  
APGSHLVPETERAEGPGVFVEHDI [SEQ ID NO:16]

MQFSIWSFTVLQISAPGSHLVPETERAEGPGVF  
VEHDI [SEQ ID NO:17]

15 MWWGLILSASVKFLQRKEILC [SEQ ID NO:18]

MVGADLCKGGWHCV [SEQ ID NO:19]

20 MREPVKNLQGLVS [SEQ ID NO:20]

MEVYELRVTLMETGRERSHFVKTSL [SEQ ID  
NO:21]

25 METGRERSHFVKTSL [SEQ ID NO:22]

MGLSAVGRTRAESGTAERAAPVFVLGLQAV  
[SEQ ID NO:23]

30 MLLWDPSGFQQISIKKVISKTLPT [SEQ ID NO:24]

MLPNTMGQLVEGGHMKQVLSKAVLTV [SEQ ID NO:25]

5 MGQLVEGGHMKQVLSKAVLTV [SEQ ID NO:26];

MKQVLSKAVLTV [SEQ ID NO:27];

MSE C [SEQ ID NO:28];

10 MAHFVAVQITV [SEQ ID NO:29];

MGICYS [SEQ ID NO:30];

MKRAGEGKSFCKGRHYSV [SEQ ID NO:31];

15 MLTTLIYYQGNSVIFVRQHSA [SEQ ID NO:32];

MQLPHFVARLFPHEQFVFIQQLSSLGKPF CRGV  
CHSV [SEQ ID NO:33];

20 MGFSKGRKCCG [SEQ ID NO:34];

MKKIWLSRKVFLYWAETL [SEQ ID NO:35];

25 MGKVHVMPLLFMESKAASINGNIMLVYVETHN  
TV [SEQ ID NO:36];

MPLLFMESKAASINGNIMLVYVETHNTV [SEQ ID  
NO:37];

30 MESKAASINGNIMLVYVETHNTV [SEQ ID NO:38];

MLVYVETHNTV [SEQ ID NO: 39];

MEEGSFIYTIKGPWMTHSLCDCCVIGFQTLALI  
GIIGEGTWWLLQGVFCLGRTHC [SEQ ID NO:40];

5

MTHSLCDCCVIGFQTLALIGIIGEGTWWLLQGV  
FCLGRTHC [SEQ ID NO:41];

10

MESQATGFCYEASHSV [SEQ ID NO:42].

Thus, both TCR and Ig chain, are now disclosed herein to be linked to the cell-cell interactions, cell growth and differentiation and thus can be used to control stromal functions. The TCR appears to be most abundant in mesenchymal stroma whereas the  $\mu$  chain seems to be abundant in endothelial stroma.

15

It is anticipated that additional molecular variants of the Ig superfamily will be transcribed and expressed on mesenchymal and/or endothelial cells and these too are within the scope of the present invention. It will be appreciated by the skilled artisan that additional molecules may be involved in molecular complexes that regulate intercellular interactions together with the novel truncated variants of the present invention.

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#### **The endothelium**

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The cellular and molecular mechanisms that allow for the maintenance of hemopoietic stem cells are inadequately understood. Morphological examination of various embryonic hemopoietic sites revealed that hemopoietic progenitor cells are in close physical contact with the endothelium in both yolk sac and aorta-gonadomesonephros region (AGM) (Lin et al 1995). The close association in the development of hemopoietic and endothelial cells during embryonic life (Garcia Porrero et al. 1995) has led to the hypothesis that the two lineages may derive from a common precursor called hemangioblast. Recently several authors reported that endothelial cells, both

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vascular endothelial cells and bone marrow endothelial cells, support hemopoiesis (Bagdy & Heinrich 1991). The mechanism by which the endothelial cells support hemopoiesis is thought to involve endothelial cell derived cytokines (Fleischman et al 1995), extracellular matrix proteins (Raffi et al 1994) and cell-cell interactions (Fina et al 1994). Stomal cells are thought to be an essential component of the lymphohematopoietic microenvironment. B lymphocytes develop in the liver during fetal life and in the bone marrow of adult animals (Kincade et al 1981). It has been suspected that yet unknown stromal cell molecules may be involved in B-lineage cell growth and development (Palacios and Samaridis 1992).

### Mesenchymal cells

Mesenchymal cells play a central role in embryogenesis by directing organogenesis. In the adult organism, tissue remodeling, such as that occurring in wound healing, is initiated by mesenchymal fibroblasts. The study of regulation of hemopoiesis demonstrated that blood cell formation is locally regulated by stromal mesenchyme (Zipori, 1989; Zipori et al., 1989; Zipori, 1990; Weintroub et al., 1996). Indeed, bone marrow-derived primary stroma as well as a variety of mesenchymal cell lines derived from primary bone marrow cultures exhibit an *in vitro* capacity to support hemopoiesis and, upon transplantation, promote the formation of bone and hemopoietically active tissue *in vivo* at the site of transplantation. The molecules that mediate the instructive stromal activities have been shown to be a variety of cytokines and adhesion molecules. However, the molecules identified thus far cannot account for the wide spectrum of stromal cell functions and certainly do not explain stroma organization, stem cell renewal and other vital stromal functions.

Mesenchymal cells from the bone marrow are well known to be obligatory for the maintenance and renewal of hemopoietic stem cells *in vitro*, and these cells are critical for the maintenance of hemopoiesis *in vivo*. This function of the mesenchyme is not restricted to blood cells. In fact, every tissue and organ is composed of a stromal mesenchyme support that interacts with the other, tissue specific cell types. Thus, the growth and differentiation of cells within different tissues, and the development of tumors, are all dependent on mesenchymal functions.

### **Knockout Mice**

Loss-of-function experiments in mice are mostly done by the technique of gene knockout. Knock-out mice employed in the present invention demonstrate the important role played by immunoglobulin superfamily variants in hemopoiesis as exemplified herein below. The technology is well known in the art. It requires the use of mouse genes for the purpose of generating knockout of the specific gene in embryonic stem (ES) cells that are then incorporated into the mouse germ-line cells from which mice carrying the gene knockout are generated. From a human gene there are several ways to recover the homologous mouse gene. One way is to use the human gene to probe mouse genomic libraries of lambda phages, cosmids or BACs. Positive clones are examined and sequenced to verify the identity of the mouse gene. Another way is to mine the mouse EST database to find the matching mouse sequences. This can be the basis for generating primer-pairs or specific mouse probes that allow an efficient screen of the mouse genomic libraries mentioned above by PCR or by hybridization. For the vast majority of genes the mouse homologue of the human gene retains the same biological function. The loss-of-function experiments in mice indicate the consequences of absence of expression of the gene on the phenotype of the mouse and the information obtained is applicable to the function of the gene in humans. On many occasions a specific phenotype observed in knockout mice was similar to a specific human inherited disease and the gene then proved to be involved and mutated in the human disease.

### **Antisense sequence**

As will be exemplified herein below, the expression or lack of expression of the mesenchymal TCR and immunoglobulin heavy chains seems to control interactions of the mesenchyme with other neighboring cells, especially in the process of hemopoiesis. The invention therefore further relates to the use of the cDNA and antisense molecules of the invention derived from mesenchymal TCR mRNAs for expression in cells and tissues for the purpose of modulating stromal/mesenchymal interactions and cell-cell communication with their neighbors in the microenvironment of the tissue involved.

For this purpose, the cDNA or antisense molecule is inserted in appropriate vectors such as, but not limited to, the retroviral vectors DCAI and DCM<sub>n</sub> that have

been used in clinical trials in gene therapy (Bordignon et al., 1995). Preferably, the vector containing the cDNA or the antisense molecule, under the control of a suitable promoter such as that cDNA's own promoter, will be used to infect or transfect suitable mammalian, preferably human, most preferably the patient's autologous mesenchymal cells. The genetically-modified mesenchymal cells are then administered to a patient in need thereof by an appropriate route and are expressed in the desired site or tissue.

In order to manipulate the expression of an undesirable gene, it is necessary to produce antisense RNA in a cell. To this end, the complete or partial cDNA of an undesirable gene in accordance with the present invention is inserted into an expression vector comprising a promoter. The 3' end of the cDNA is thereby inserted adjacent to the 3' end of the promoter, with the 5' end of the cDNA being separated from the 3' end of the promoter by said cDNA. Upon expression of the cDNA in a cell, an antisense RNA is therefore produced which is incapable of coding for the protein. The presence of antisense RNA in the cell reduces the expression of the cellular (genomic) copy of the undesirable gene.

For the production of antisense RNA, the complete cDNA may be used. Alternatively, a fragment thereof may be used, which is preferably between about 9 and 2,000 nucleotides in length, more preferably between 15 and 500 nucleotides, and most preferably between 30 and 150 nucleotides.

The fragment is preferably corresponding to a region within the 5' half of the cDNA, more preferably the 5' region comprising the 5' untranslated region and/or the first exon region, and most preferably comprising the ATG translation start site. Alternatively, the fragment may correspond to DNA sequence of the 5' untranslated region only.

A synthetic oligonucleotide may be used as antisense oligonucleotide. The oligonucleotide is preferably a DNA oligonucleotide. The length of the antisense oligonucleotide is preferably between 9 and 150, more preferably between 12 and 60, and most preferably between 15 and 50 nucleotides. Suitable antisense oligonucleotides that inhibit the production of the protein of the present invention from its encoding mRNA can be readily determined with only routine experimentation through the use of a series of overlapping oligonucleotides similar to a "gene walking" technique that is well-known in the art. Such a "walking" technique as well-known in the art of antisense

development can be done with synthetic oligonucleotides to walk along the entire length of the sequence complementary to the mRNA in segments on the order of 9 to 150 nucleotides in length. This "gene walking" technique will identify the oligonucleotides that are complementary to accessible regions on the target mRNA and exert inhibitory antisense activity.

Alternatively, an oligonucleotide based on the coding sequence of a protein capable of binding to an undesirable gene or the protein encoded thereby can be designed using Oligo 4.0 (National Biosciences, Inc.). Antisense molecules may also be designed to inhibit translation of an mRNA into a polypeptide by preparing an antisense which will bind in the region spanning approximately -10 to +10 nucleotides at the 5' end of the coding sequence.

Modifications of oligonucleotides that enhance desired properties are generally used when designing antisense oligonucleotides. For instance, phosphorothioate bonds are used instead of the phosphoester bonds that naturally occur in DNA, mainly because such phosphorothioate oligonucleotides are less prone to degradation by cellular enzymes. Preferably, a 2' -methoxyribonucleotide modification in 60% of the oligonucleotides is used. Such modified oligonucleotides are capable of eliciting an antisense effect comparable to the effect observed with phosphorothioate oligonucleotides.

Therefore, the preferred antisense oligonucleotide of the present invention has a mixed phosphodiester-phosphorothioate backbone. Preferably, 2'-methoxyribonucleotide modifications in about 30% to 80%, more preferably about 60%, of the oligonucleotide are used.

In the practice of the invention, antisense oligonucleotides or antisense RNA may be used. The length of the antisense RNA is preferably from about 9 to about 3,000 nucleotides, more preferably from about 20 to about 1,000 nucleotides, most preferably from about 50 to about 500 nucleotides.

In order to be effective, the antisense oligonucleotides of the present invention must travel across cell membranes. In general, antisense oligonucleotides have the ability to cross cell membranes, apparently by uptake via specific receptors. As the antisense oligonucleotides are single-stranded molecules, they are to a degree hydrophobic, which enhances passive diffusion through membranes. Modifications

may be introduced to an antisense oligonucleotide to improve its ability to cross membranes. For instance, the oligonucleotide molecule may be linked to a group, which includes a partially unsaturated aliphatic hydrocarbon chain, and one or more polar or charged groups such as carboxylic acid groups, ester groups, and alcohol groups. Alternatively, oligonucleotides may be linked to peptide structures, which are preferably membranotropic peptides. Such modified oligonucleotides penetrate membranes more easily, which is critical for their function and may, therefore, significantly enhance their activity.

#### **Introduction of Proteins, Peptides, and DNA into Cells**

The present invention provides proteins encoded by the truncated immunoglobulin superfamily variant genes, peptides derived therefrom and antisense DNA molecules based on the variant gene transcripts. A therapeutic or research-associated use of these tools necessitates their introduction into cells of a living organism or into cultured cells. For this purpose, it is desired to improve membrane permeability of peptides, proteins and antisense molecules. The same principle, namely, derivatization with lipophilic structures, may also be used in creating peptides and proteins with enhanced membrane permeability. For instance, the sequence of a known membranotropic peptide may be added to the sequence of the peptide or protein. Further, the peptide or protein may be derivatized by partly lipophilic structures such as the above-noted hydrocarbon chains, which are substituted with at least one polar or charged group. For example, lauroyl derivatives of peptides have been described in the art. Further modifications of peptides and proteins include the oxidation of methionine residues to thereby create sulfoxide groups and derivatives wherein the relatively hydrophobic peptide bond is replaced by its ketomethylene isoester (COCH<sub>2</sub>) have been described. It is known to those of skill in the art of protein and peptide chemistry these and other modifications enhance membrane permeability.

Another way of enhancing membrane permeability is to make use of receptors, such as virus receptors, on cell surfaces in order to induce cellular uptake of the peptide or protein. This mechanism is used frequently by viruses, which bind specifically to certain cell surface molecules. Upon binding, the cell takes the virus up into its interior. The cell surface molecule is called a virus receptor. For instance, the integrin molecules

CAR and AdV have been described as virus receptors for Adenovirus. The CD4, GPR1, GPR15, and STRL33 molecules have been identified as receptors/ coreceptors for HIV.

By conjugating peptides, proteins or oligonucleotides to molecules that are known to bind to cell surface receptors, the membrane permeability of said peptides, proteins or oligonucleotides will be enhanced. Examples of suitable groups for forming conjugates are sugars, vitamins, hormones, cytokines, transferrin, asialoglycoprotein, and the like molecules. Low et al U.S. Patent 5,108,921 describes the use of these molecules for the purpose of enhancing membrane permeability of peptides, proteins and oligonucleotides, and the preparation of said conjugates.

Low and coworkers further teach that molecules such as folate or biotin may be used to target the conjugate to a multitude of cells in an organism, because of the abundant and nonspecific expression of the receptors for these molecules.

The above use of cell surface proteins for enhancing membrane permeability of a peptide, protein or oligonucleotide of the invention may also be used in targeting the peptide, protein or oligonucleotide of the present invention to certain cell types or tissues. For instance, if it is desired to target neural cells, it is preferable to use a cell surface protein that is expressed more abundantly on the surface of those cells.

The protein, peptide or oligonucleotide of the invention may therefore, using the above-described conjugation techniques, be targeted to mesenchymal cells. For instance, if it is desired to enhance mesenchymal cell growth in order to augment autologous or allogeneic bone marrow transplantation or wound healing, then the immunoglobulin superfamily variant genes could be inserted into mesenchymal cells as a form of gene therapy. In this embodiment, local application of the cells containing the cDNA molecule can be used to modulate mesenchymal cell-cell interactions with neighboring cells in the microenvironment thus enhancing the wound healing process

In contrast, it is often desirable to inhibit mesenchymal cell-cell interactions, as in the case of a tumor. Therefore, mesenchymal cells of the tumor can be transfected with the antisense cDNA and then be used for treatment of localized solid tumors, to achieve regression of the tumor by blocking mesenchyme intercellular communication.

The proteins encoded by the mRNAs of the invention are cell surface receptors of mesenchymal cells and may probably interact with ligands presented by neighboring hemopoietic or non-hemopoietic cells. Thus, in bound or soluble form, these proteins or

the peptides derived therefrom, may have modulatory effects on cells that bear said ligands.

### **Antibodies**

5           The present invention also comprehends antibodies specific for the polypeptides or peptides encoded by the truncated immunoglobulin superfamily variant transcripts, which are part of the present invention as discussed above. The proteins and peptides of the invention may be used as immunogens for production of antibodies that may be used as markers of mesenchymal cells. Such an antibody may be used for diagnostic  
10       purposes to identify the presence of any such naturally-occurring proteins. Such antibody may be a polyclonal antibody or a monoclonal antibody or any other molecule that incorporates the antigen-binding portion of a monoclonal antibody specific for such a protein. Such other molecules may be a single-chain antibody, a humanized antibody, an F(ab) or F(ab')<sub>2</sub> fragment, a chimeric antibody, an antibody to which is attached a  
15       label, such as fluorescent or radioactive label, or an immunotoxin in which a toxic molecule is bound to the antigen binding portion of the antibody. The examples are intended to be non-limiting. However, as long as such a molecule includes the antigen-binding portion of the antibody, it will be expected to bind to the protein and, thus, can be used for the same diagnostic purposes for which a monoclonal antibody can be used.

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### **Pharmaceutical compositions**

          These compositions are for use by injection, topical administration, or oral uptake. Preferred uses of the pharmaceutical compositions of the invention topically (including intraocularly, vaginally, rectally, intranasally and by inhalation), orally, or  
25       parenterally, for example by intravenous drip or intraperitoneal, subcutaneous, or intramuscular injection.

          The pharmaceutical composition of the invention generally comprises a buffering agent, an agent which adjusts the osmolarity thereof, and optionally, one or more carriers, excipients and/or additives as known in the art, e.g., for the purposes of  
30       adding flavors, colors, lubrication, or the like to the pharmaceutical composition.

Carriers are well known in the art and may include starch and derivatives thereof, cellulose and derivatives thereof, e.g., microcrystalline cellulose, xanthan gum, and the like. Lubricants may include hydrogenated castor oil and the like.

5 A preferred buffering agent is phosphate-buffered saline solution (PBS), which solution is also adjusted for osmolarity.

A preferred pharmaceutical formulation is one lacking a carrier. Such formulations are preferably used for administration by injection, including intravenous injection.

10 The preparation of pharmaceutical compositions is well known in the art and has been described in many articles and textbooks.

Additives may also be selected to enhance uptake of the antisense oligonucleotide across cell membranes. Such agents are generally agents that will enhance cellular uptake of double-stranded DNA molecules. For instance, certain lipid molecules have been developed for this purpose, including the transfection reagents  
15 DOTAP (Boehringer Mannheim), Lipofectin, Lipofectam, and Transfectam, which are available commercially. The antisense oligonucleotide of the invention may also be enclosed within liposomes.

The preparation and use of liposomes, e.g., using the above-mentioned transfection reagents, is well known in the art. Other methods of obtaining liposomes  
20 include the use of Sendai virus or of other viruses.

The above-mentioned cationic or nonionic lipid agents not only serve to enhance uptake of oligonucleotides into cells, but also improve the stability of oligonucleotides that have been taken up by the cell.

## 25 **Detection of Protein Products of Genes of Interest**

Techniques for detecting a protein translation product of interest include, but are not limited to, immunoblotting or Western blotting, ELISA, sandwich assays, fluorescence, or biotin or enzymatic labeling with or without secondary antibodies.

Western blot analysis can be done on the tissue biopsies or tissue aspirates. This  
30 would involve resolving the proteins on an electrophoretic gel, such as an SDS PAGE gel, and transferring the resolved proteins onto a nitrocellulose or other suitable

membrane. The proteins are incubated with a target binding molecule, such as an antibody.

This binding reagent may be labeled or not. If it were unlabeled, then one would also employ a secondary, labeled molecule which binds to the binding reagent. One approach involves avidinating one molecule and biotinylating the other. Another is for the secondary molecule to be a secondary antibody, which binds the original binding reagent.

To improve detection of the specific protein, immunoprecipitation can be conducted. This typically will involve addition of a monoclonal antibody against the protein of interest to samples, then allowing the Ig-protein complex to precipitate after the addition of an affinity bead (ie antihuman Ig Sepharose bead). The immunoprecipitates will undergo several washings prior to transfer onto a nitrocellulose membrane. The Western blot analysis can be performed using another antibody against the primary antibody used.

Having now generally described the invention, the same will be more readily understood through reference to the following example, which is provided by way of illustration and is not intended to be limiting of the present invention.

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## EXAMPLES

### Primary cell cultures

(i) Bone marrow: Mouse bone marrow cells were obtained from femur and tibia of 1-2 week old female C57BL/6 mice. Bone marrow cells were removed aseptically by flushing culture medium through the marrow cavity using a 1ml syringe fitted with a 27-gauge needle.  $1 \times 10^7$  cells/ml were seeded in DMEM with 20% FCS (Bio Lab, Israel) and cultured for 4-5 days at 37°C and 5% CO<sub>2</sub> atmosphere. The plates were washed and covered with fresh culture medium. After 3 weeks, a monolayer was formed. The cells were passaged monthly at a split ratio of 1:10 using 0.5% trypsin (Sigma, St. Louis, MO) containing 0.02% EDTA.

(ii) Embryonic fibroblasts: Mouse embryo were minced in PBS solution and treated with 0.5% trypsin and 0.02% EDTA at 37°C for 15 minutes. The supernatant

was collected and treated again with trypsin for 30 minutes. The cell suspension obtained was then washed a few times, resuspended in DMEM containing 10% FCS to a final concentration of  $1 \times 10^6$  cells/ml, and cultured for 4-5 days at 37°C and 5% CO<sub>2</sub> atmosphere. When a fibroblast monolayer was formed, it was trypsinized for 5 minutes, and the cells were washed and resuspended as indicated before. This cell suspension ( $2 \times 10^5$  cells/ml) was cultured again for 4-5 days and then collected.

(iii) Thymus and liver cells were obtained from Balb/c mice, 6-10 weeks old.

#### **Long term hemopoietic cultures**

Bone marrow cells from Balb/C mice at  $5 \times 10^5$  per culture, or  $10^3$  FACS sorted CD34<sup>+</sup> Lin<sup>-</sup> cells, were seeded onto a confluent layer of MEF that were passaged prior to use 3-13 times *in vitro*. Bone marrow cells were seeded in  $\alpha$ -MEM (Gibco-BRL, Paisley, UK) supplemented with 20% horse serum (StemCell Technologies, Vancouver, Canada) and  $10^{-6}$  hydrocortisone hemisuccinate and were maintained at 33°C in a humidified atmosphere of 10% CO<sub>2</sub> in air. In each experiment, 6 individual cultures from each group were seeded. The cultures were demidepopulated and refed twice weekly. The cells collected were counted and seeded in semisolid methylcellulose medium supplemented with interleukin (IL)-3 (10 ng/ml), erythropoietin (3 units/ml), ckit ligand (50 ng/ml) and IL-6 (10 ng/ml). Ckit ligand was purchased from PeproTech Inc. Rocky Hill, NJ and the other cytokines from R&D Systems, Minneapolis, MN. Colonies were counted at day 8 in culture.

#### **Statistics:**

Data are presented as the mean  $\pm$  standard error of the mean. Student's t-test was performed to determine significance.

#### **Defective Hemopoiesis of MEF from TCR $\beta$ Deficient Mice**

One commonly studied function of the mesenchyme is the capacity to form an *in vitro* microenvironment suitable for the self-renewal and differentiation of hemopoietic stem cells. We utilized this phenomenon to compare the ability of normal MEF to those from TCR $\beta^{-/-}$  mice in their ability to support long term *in vitro* hemopoiesis. Bone marrow cells from donor Balb/C mice (Figure 1A) or FACS sorted purified population of CD34<sup>+</sup> Lin<sup>-</sup> cells enriched for hemopoietic stem cells (Figure 1B-I&C) seeded onto confluent

cultures of MEF from normal mice formed cobblestone areas within a few days culture and proliferated throughout one month of incubation within the MEF layer and in the liquid phase of the cultures. Hemopoietic colony formation assays detected in these cultures high incidence of hemopoietic progenitors (Figure 1D). These findings were identical for MEF  
5 passaged 3-13 times in culture. By sharp contrast, MEF from  $\text{TCR}\beta^{-/-}$  mice at early passages had inferior capacity to support hemopoiesis (not shown) and entirely lost this capacity when passaged over 7 times (Figure 1A, B-II and C). It is noteworthy, that MEF from  $\text{TCR}\beta^{-/-}$  and wild type animals proliferated at this stage with the same population doubling times and did not show signs of morphological transformation. It remains to be determined  
10 whether TCR directly interacts with hemopoietic stem cells or whether its effect on mesenchymal hemopoietic functions is mediated indirectly. Our findings indicate that  $\text{TCR}\beta$  knockout does not only result in a T cell defect but also causes a primary mesenchymal malfunctioning.

#### 15 **Mesenchymal Cells Express Other Members of the Immunoglobulin Superfamily**

The finding that mesenchymal cells express TCR genes raised the possibility that other members of the immunoglobulin (Ig) superfamily are expressed in the mesenchyme. We screened a series of stromal mesenchymal cell lines derived in our laboratory including one subtype that shares properties with endothelial cells (MBA-2.1  
20 cells). Using RT-PCR we discovered that the MBA-2.1 cells express an abundant amount of mouse  $\mu$  chain mRNA. Northern blot analysis (Figure 2) verifies that this is the case. More importantly, we obtained evidence that the  $\mu$  chain protein is expressed by this cell line. Indeed, Western blotting detected a band that corresponds to about 50 kDa in size (Figure 3) which is the size predicted by the mRNA sequence.

25 The truncated  $\mu$  heavy chain (mouse)-MBA2.1 comprises the DNA sequence designated I+j2 [SEQ ID NO:1] which encodes peptide with the sequence [SEQ ID NO:2]. In addition, one form of the truncated  $\mu$  heavy chain 5' begins from J4 and extends through the C region and contains either a transmembrane domain, [SEQ ID NO:3] or a cytoplasmic domain [SEQ ID NO:4]. Another form of the truncated  $\mu$  heavy  
30 chain 5' begins from the constant region and contains either a transmembrane domain [SEQ ID NO:5] or a cytoplasmic domain [SEQ ID NO:6].

The case of the truncated  $\mu$  heavy chain is very similar to the case of the truncated TCR $\beta$ . In the mesenchyme and endothelium, there is expression of Ig superfamily molecules that are truncated i.e. lacking the variable part and possessing a J region preceded by an intronic sequence including a codon for methionine. PCR analysis verified that MBA-2.1 cells do express such an mRNA. We thus find that at least one type, and possibly more, of stromal and endothelial cells express the Ig  $\mu$  chain and may present this protein as a surface molecule. The expression of the  $\mu$  chain by the mesenchyme and endothelium is expected to regulate or be associated with intercellular growth/differentiation control their neighboring cells. Both TCR and  $\mu$  chain, are known to be linked to the cell growth/differentiation machinery and thus can be used to modulate mesenchymal and endothelial intercellular interactions. The TCR appears to be most abundant in mesenchymal stroma whereas the  $\mu$  chain seems to be abundant in endothelial stroma.

Lastly, to strengthen the results of the Western blot, Fig. 4 depicts immunostaining of MBA 2.1 cells with goat anti mouse-  $\mu$  chain and amplified with biotinylated donkey anti goat and ABC kit.

#### **Use of Mesenchymal and Endothelial TCR or Ig in Control of Neighboring Cell Growth or Differentiation**

The cDNAs encoding these molecules can be used to control cell growth by either expressing the sense or the antisense sequences, depending on the intended purpose of the treatment. In the case of tumors the stroma enhances tumor growth. It is therefore desirable to inhibit or ultimately to block this effect of stromal cells on the tumor cells and thus it is appropriate to apply the antisense to either of the genes in order to shut off their expression. The same thing is true for diseases such as myelofibrosis when the bone marrow becomes loaded with mesenchymal cells that block normal hemopoiesis and should be eliminated.

In order to manipulate the expression of an undesirable gene, it is desirable to produce antisense RNA in a cell. To this end, the complete or partial cDNA of an undesirable gene in accordance with the present invention is inserted into an expression vector comprising a promoter. The 3' end of the cDNA is thereby inserted adjacent to the 3' end of the promoter, with the 5' end of the cDNA being separated from the 3' end

of the promoter by said cDNA. Upon expression of the cDNA in a cell, an antisense RNA is therefore produced which is incapable of coding for the protein. The presence of antisense RNA in the cell reduces the expression of the cellular (genomic) copy of the undesirable gene.

5           For the production of antisense RNA, the complete cDNA may be used. Alternatively, a fragment thereof may be used, which is preferably between about 9 and 2,000 nucleotides in length, more preferably between 15 and 500 nucleotides, and most preferably between 30 and 150 nucleotides.

10           The fragment is preferably corresponding to a region within the 5' half of the cDNA, more preferably the 5' region comprising the 5' untranslated region and/or the first exon region, and most preferably comprising the ATG translation start site. Alternatively, the fragment may correspond to DNA sequence of the 5' untranslated region only.

15           A synthetic oligonucleotide may be used as antisense oligonucleotide. The oligonucleotide is preferably a DNA oligonucleotide. The length of the antisense oligonucleotide is preferably between 9 and 150, more preferably between 12 and 60, and most preferably between 15 and 50 nucleotides. Suitable antisense oligonucleotides that inhibit the production of the protein of the present invention from its encoding mRNA can be readily determined with only routine experimentation through the use of  
20           a series of overlapping oligonucleotides similar to a "gene walking" technique that is well-known in the art. Such a "walking" technique as well known in the art of antisense development can be done with synthetic oligonucleotides to walk along the entire length of the sequence complementary to the mRNA in segments on the order of 9 to 150 nucleotides in length. This "gene walking" technique will identify the oligonucleotides  
25           that are complementary to accessible regions on the target mRNA and exert inhibitory antisense activity.

30           Alternatively, an oligonucleotide based on the coding sequence of a protein capable of binding to an undesirable gene or the protein encoded thereby can be designed using Oligo 4.0 (National Biosciences, Inc.). Antisense molecules may also be designed to inhibit translation of an mRNA into a polypeptide by preparing an antisense which will bind in the region spanning approximately -10 to +10 nucleotides at the 5' end of the coding sequence.

Modifications of oligonucleotides that enhance desired properties are generally used when designing antisense oligonucleotides. For instance, phosphorothioate bonds are used instead of the phosphoester bonds that naturally occur in DNA, mainly because such phosphorothioate oligonucleotides are less prone to degradation by cellular enzymes. Preferably, 2'-methoxyribonucleotide modifications in 60% of the oligonucleotide is used. Such modified oligonucleotides are capable of eliciting an antisense effect comparable to the effect observed with phosphorothioate oligonucleotides.

Therefore, the preferred antisense oligonucleotide of the present invention has a mixed phosphodiester-phosphorothioate backbone. Preferably, 2'-methoxyribonucleotide modifications in about 30% to 80%, more preferably about 60%, of the oligonucleotide are used.

In the practice of the invention, antisense oligonucleotides or antisense RNA may be used. The length of the antisense RNA is preferably from about 9 to about 3,000 nucleotides, more preferably from about 20 to about 1,000 nucleotides, most preferably from about 50 to about 500 nucleotides.

In order to be effective, the antisense oligonucleotides of the present invention must travel across cell membranes. In general, antisense oligonucleotides have the ability to cross cell membranes, apparently by uptake via specific receptors. As the antisense oligonucleotides are single-stranded molecules, they are to a degree hydrophobic, which enhances passive diffusion through membranes. Modifications may be introduced to an antisense oligonucleotide to improve its ability to cross membranes. For instance, the oligonucleotide molecule may be linked to a group, which includes a partially unsaturated aliphatic hydrocarbon chain, and one or more polar or charged groups such as carboxylic acid groups, ester groups, and alcohol groups. Alternatively, oligonucleotides may be linked to peptide structures, which are preferably membranotropic peptides. Such modified oligonucleotides penetrate membranes more easily, which is critical for their function and may, therefore, significantly enhance their activity.

The antisense oligonucleotides of the invention are generally provided in the form of pharmaceutical compositions. These compositions are for use by injection, topical administration, or oral uptake.

### **Pharmaceutical Compositions**

Preferred uses of the pharmaceutical compositions of the invention by injection are subcutaneous injection, intravenous injection, and intramuscular injection. Less convenient routes of administration may include intraperitoneal, intradural, intra-theal  
5 administration or intra-arterial administration when required.

The pharmaceutical composition of the invention generally comprises a buffering agent, an agent which adjusts the osmolarity thereof, and optionally, one or more carriers, excipients and/or additives as known in the art, e.g., for the purposes of adding flavors, colors, lubrication, or the like to the pharmaceutical composition.

10 Carriers may include starch and derivatives thereof, cellulose and derivatives thereof, e.g., microcrystalline cellulose, xanthan gum, and the like. Lubricants may include hydrogenated castor oil and the like.

A preferred buffering agent is phosphate-buffered saline solution (PBS), which solution is also adjusted for osmolarity.

15 A preferred pharmaceutical formulation is one lacking a carrier. Such formulations are preferably used for administration by injection, including intravenous injection. The preparation of pharmaceutical compositions is well known in the art.

Additives may also be selected to enhance uptake of the antisense oligonucleotide across cell membranes. Such agents are generally agents that will  
20 enhance cellular uptake of double-stranded DNA molecules. For instance, certain lipid molecules have been developed for this purpose, including the transfection reagents DOTAP (Boehringer Mannheim), Lipofectin, Lipofectam, and Transfectam, which are available commercially. The antisense oligonucleotide of the invention may also be enclosed within liposomes. The preparation and use of liposomes, e.g., using the above-  
25 mentioned transfection reagents, is well known in the art.

### **Gene therapy**

On the other hand it may be important to increase the expression of the TCR gene in conditions requiring more augmented intercellular mesenchymal interactions such as in improper wound healing, for example by means of gene therapy. By the same  
30 token, the  $\mu$  chain may have overlapping or complementary functions to TCR and may be used in a similar manner, for other purposes relating to endothelium, i.e. to suppress neo-vascularization in tumors on the one hand and to enhance vascularization in

diseases that involve defective blood vessel formation, on the other. Our present experiments show that the TCR affects hemopoiesis, and it is likely that the  $\mu$  chain has similar or complementary functions.

5 Recently, gene transfer into hematopoietic cells using viral vectors has focused  
mostly on lymphocytes and hematopoietic stem cells (HSCs). HSCs have been  
considered particularly important as target cells because of their pluripotency and ability  
to reconstitute hemopoiesis after myeloablation and transplantation. HSCs are believed  
to have the ability to live a long time, perhaps a lifetime, in the recipient following bone  
marrow transplantation. Genetic correction of HSCs can therefore potentially last a  
10 lifetime and permanently cure hematologic disorders in which genetic deficiencies  
cause the pathology. Oncoretroviral vectors have been the main vectors used for HSCs  
because of their ability to integrate into the chromosomes of their target cells. Gene-  
transfer efficiency of murine HSCs is high using oncoretroviral vectors. In contrast,  
gene-transfer efficiency using the same viral vectors to transduce human HSCs or HSCs  
15 from large animals has been much lower. Although these difficulties may have several  
causes, the main reason for the low efficiency of human HSC transduction with  
oncoretroviral vectors is probably because of the nondividing nature of HSCs. Murine  
HSCs can be easily stimulated to divide in culture, whereas it is more problematic to  
stimulate human HSCs to divide rapidly in vitro. Because oncoretroviral vectors require  
20 dividing target cells for successful nuclear import of the preintegration complex and  
subsequent integration of the provirus, only the dividing fraction of the target cells can  
be transduced.

In addition, adenovirus (Adv)-mediated gene transfer has recently gained new  
attention as a means to deliver genes for hematopoietic stem cell (HSC) or progenitor  
25 cell gene therapy. In the past, HSCs have been regarded as poor Adv targets, mainly  
because they lack the specific Adv receptors required for efficient and productive Adv  
infection. In addition, the nonintegrating nature of Adv has prevented its application to  
HSC and bone marrow transduction protocols where long-term expression is required.  
There is even controversy as to whether Adv can infect hematopoietic cells at all. In  
30 fact, the ability of Adv to infect epithelium-based targets and its inability to effectively  
transfect HSCs have been used in the development of eradication schemes that use Adv  
to preferentially infect and "purge" tumor cell-contaminating HSC grafts. However,

there are data supporting the existence of productive Adv infections into HSCs. Such protocols involve the application of cytokine mixtures, high multiplicities of infection, long incubation periods, and more recently, immunological and genetic modifications to Adv itself to enable it to efficiently transfer genes into HSCs. This is a rapidly growing  
5 field, both in terms of techniques and applications.

Having now fully described certain preferred embodiments of this invention, it will be appreciated by those skilled in the art that the same can be performed within a wide range of equivalent parameters, concentrations, and conditions without departing from the spirit and scope of the invention and without undue experimentation.

10 While this invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modifications. This application is intended to cover any variations, uses, or adaptations of the inventions following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice  
15 within the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth as follows in the scope of the appended claims.

All references cited herein, including journal articles or abstracts, published or unpublished U.S. or foreign patent applications, issued U.S. or foreign patents, or any other references, are entirely incorporated by reference herein, including all data, tables,  
20 figures, and text presented in the cited references. Additionally, the entire contents of the references cited within the references cited herein are also entirely incorporated by reference.

Reference to known method steps, conventional method steps, known methods or conventional methods is not in any way an admission that any aspect, description or  
25 embodiment of the present invention is disclosed, taught or suggested in the relevant art.

The foregoing description of the specific embodiments will so fully reveal the general nature of the invention that others can, by applying knowledge within the skill of the art (including the contents of the references cited herein), readily modify and/or adapt for various applications such specific embodiments, without undue  
30 experimentation, without departing from the general concept of the present invention. Therefore, such adaptations and modifications are intended to be within the meaning and range of equivalents of the disclosed embodiments, based on the teaching and

guidance presented herein. It is to be understood that the phraseology or terminology herein is for the purpose of description and not of limitation, such that the terminology or phraseology of the present specification is to be interpreted by the skilled artisan in light of the teachings and guidance presented herein, in combination with the  
5 knowledge of one of ordinary skill in the art.

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